

We claim:

1. An apparatus for transmitting information on the physical status of a

subject comprising

a carrier for sensors arranged to be worn by the subject for providing electrical

signals representative of physical parameters of the subject, and

electronics to receive the electrical signals from the sensors, and to process the signals at the location of the subject,

said sensors including one or more respiration motion sensors comprising

a flexible strip having a first conductive lead connecting to an area of

resistive material whose electrical resistance varies as the strip is flexed.

2. The apparatus of claim 1 wherein the flexible strip is a film laminated to a

stiffer base layer comprising an arched portion, wherein the area of resistive material is

located on the arched portion.

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3. The apparatus of claim 2 wherein the film strip and base layer are formed so that the portion of the strip containing the resistive material is shaped into an arch.

4. The apparatus of claim 1 wherein the flexible strip is a film laminated to

the stiffer base layer using a flexible adhesive.

5. The apparatus of claim 1 wherein the area of resistive material is less than

half a square centimeter.

6. The apparatus of claim 1 wherein the area of resistive material has a rectangular shape with an upper surface area less than half a square centimeter.

7. The apparatus of claim 6 wherein the strip has ends that are substantially flat.

8. The apparatus of claim 1 wherein the carrier further comprises a central housing for the electronics, two extensions from the central housing carrying external sensors, and a harness.

9. The apparatus of claim 8 wherein the harness is configured to position the housing approximately over the subject's solar plexus.

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10. The apparatus of claim 9, wherein the harness has an elastic portion and comprises a first strap that passes around the subject's back and a second strap that passes over the left shoulder.

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11. The apparatus of claim 10 wherein the two extensions extend from the sides of the housing and are connected to the first strap of the harness.

12. The apparatus of claim 8 wherein the straps of the harness have  
adjustable lengths to allow fitting to different users.

13. The apparatus of claim 1 comprising electrical contacts on the flexible strip  
5 for connection with the electronics and a second conductive lead on the flexible strip  
joined to the first conductive lead at the end of the sensor opposite the contacts.

14. The apparatus of claim 13 comprising electrical contacts and having  
improved electromagnet interference rejection comprising a third conductive lead on the  
10 flexible strip, said second and third conductive leads located on opposite sides of the  
first conductive lead, and the three conductive leads joined at an end opposite the  
contacts.

15. The apparatus of claim 1 further comprising a cover sheet overlaying the  
.5 resistive material.

16. The apparatus of claim 1 further comprising a cover sheet adhered to the  
resistive material.

17. The apparatus of claim 1 comprising a voltage divider circuit having two  
resistors in which one of the resistors comprises the area of resistive material.

18. The apparatus of claim 1 comprising a decoupling circuit so that an output signal from the respiration motion sensor is proportional to changes in resistance of the area of resistive material.

19. The apparatus of claim 2 wherein the resistance of the area of resistive material increases as the arched portion of the strip is flexed convexly.

20. The apparatus of claim 1 wherein the respiration sensor comprises a second flexible strip having a second area of resistive material, wherein the two flexible strips are back-to-back on a single base layer.

21. The apparatus of claim 20 wherein the two areas of resistive material are in series and connected between fixed voltages, thus creating a voltage divider.

22. A carrier for sensors arranged to be worn by the subject for providing electrical signals representative of physical parameters of the subject, said carrier comprising

a central housing,

two flexible extensions containing

sensors including a respiration motion sensor,

a harness, and

electronics to receive and interpret the electrical signals from the sensors, and to

process the signals at the location of the subject,

    said respiration motion sensor comprising a flex sensor having an arched structure with a radius of curvature and an electrical resistance dependant upon the radius of curvature,

    said harness comprising an attachment to the subject that causes the radius of curvature of the arched structure to vary in response to motion of the abdomen of the subject, wherein the electronics wirelessly transmits information representative of the motion of the abdomen of the subject during respiration.

) 23. The carrier for sensors of claim 22 comprising one or more respiration sensors, each respiration sensor sewn to a front surface of one of the extensions.

24. The carrier for sensors of claim 22 wherein the respiration sensor is aligned along the extension.

5 25. The carrier for sensors of claim 22, wherein a portion of the extensions under an arched section of a respiration motion sensor is substantially compliant to tensile load so that the tension load when the carrier is worn is mainly across the respiration motion sensor.

0 26. The carrier for sensors of claim 22, wherein a cover material is placed over the extensions so arranged not to interfere with flexure of the arch of the respiration motion sensor.

27. A respiration motion sensor for inclusion in a carrier to be worn by a subject, said sensor comprising a deformation transducer element having an arched portion with an electrical resistance that varies as the chest or abdomen of the subject expands and contracts due to respiration.

28. The respiration motion sensor of claim 27 comprising a flexible, variable resistance element and a compliant backing or support element.

29. The respiration motion sensor of claim 27 wherein the respiration motion sensor comprises a flexible element having a radius of curvature and an electrical resistance that increases as the radius of curvature of the flexible element decreases.

30. The respiration motion sensor of claim 27 wherein the electrical resistance has a minimum value when the flexible element is flattened.

31. A carrier for sensors arranged to be worn by a subject comprising two flexible extensions each containing a respiration motion sensor comprising a flexible deformation transducer element that varies in electrical resistance as the chest or abdomen of the subject expands and contracts due to respiration, wherein each flexible deformation transducer has a preset non-zero

curvature and a maximum resistance when no load is applied.

32. The carrier for sensors of claim 31 further comprising a harness attached to the two flexible extensions such that a tensile load is applied to the flexible deformation transducer element when the subject is taking a breath.

33. The carrier for sensors of claim 32, wherein the tensile load will tend to reduce the curvature of the flexible deformation transducer, thus decreasing its electrical resistance.

34. The carrier for sensors of claim 31 wherein the flexible deformation transducer element has a backing or support element that limits the degree of deformation of the flexible element.

5 35. The carrier for sensors of claim 31, wherein the change in resistance during breathing is approximately proportional to the load to the flexible deformation transducer during breathing.

0 36. A carrier for sensors arranged to be worn by a subject on its abdomen comprising  
a flattened body shaped to conform to the abdomen having two projecting arms,  
a bending sensor transducer assembly attached between the two projecting arms

such that the rotation of either arm relative to the other will produce a change in electrical resistance of the bending sensor,  
a flexible pad or backing on one side of the transducer assembly,  
a pressure applicator that compresses the assembly against the subject's abdomen, oriented so that the flexible pad or backing is placed flat against the skin.

37. The carrier for sensors arranged to be worn by a subject on its abdomen of claim 36, wherein the pressure applicator comprises a belt or strap, an external clamp or fixture, or an adhesive pad that attaches to the skin.

38. The carrier for sensors arranged to be worn by a subject on its abdomen of claim 36, wherein the pressure applicator is configured such that force is applied near proximal and distal ends of each projecting arm with approximately equal force, wherein the flexible pad conforms to the curvature of the skin.

39. The carrier for sensors arranged to be worn by a subject on its abdomen of claim 38, wherein the pressure applicator is further configured such that the mechanical compliance of the pressing elements is greater at the proximal ends than at the distal ends of the arms.

40. A carrier for sensors arranged to be worn by a subject on its abdomen wherein the skin and underlying tissue of the abdomen are pressed by two flat

extensions that are connected by an arched section on which a resistive sensing element is mounted.

41. The carrier for sensors arranged to be worn by a subject on its abdomen of claim 40 wherein a rigid or semi-rigid backing is fixed at a short distance from the skin surface and compliant elements fit between the backing and the flat extensions and press the flat extensions against the skin.

42. The carrier for sensors arranged to be worn by a subject on its abdomen of claim 41 wherein the compliant elements are springy material.

43. The carrier for sensors arranged to be worn by a subject on its abdomen of claim 42, wherein the compliant elements at the proximal ends of the extension have a different degree of compliance than the compliant elements near distal ends.

44. The carrier for sensors arranged to be worn by a subject on its abdomen of claim 43, wherein the compliant elements at distal ends may have the greater compliance or to be rigid.

45. The carrier for sensors arranged to be worn by a subject on its abdomen of claim 40, wherein a pad or separator lies between the flat extensions and the skin.

46. An apparatus for transmitting information on the physical status of a subject comprising
- a carrier for sensors arranged to be worn by the subject for providing electrical signals representative of physical parameters of the subject,
- electronics to receive the electrical signals from the sensors, and to process the signals at the location of the subject and wirelessly transmit information on the physical state of the subject,
- said sensors including a flex sensor comprising an arched structure having a radius of curvature and an electrical resistance dependant upon the radius of curvature,
- an attachment to the subject that causes the radius of curvature of the arched structure to vary in response to motion of the abdomen of the subject, wherein the apparatus wirelessly transmits information representative of the motion of the abdomen of the subject during respiration.

- 5       47. A process for forming a respiration motion sensor comprising
- forming a flexible film strip overprinted with conductive leads connecting to an area of resistive material whose resistance varies as the strip is flexed,
- laminating the film strip to a stiffer base layer using a flexible adhesive, and
- forming the film strip and base layer so that the portion of the strip containing the
- .0      small resistive area is shaped into an arch while the ends of the strip remain substantially flat.

48. The process for forming a respiration motion sensor of claim 47, wherein the operating range of the sensor is shifted to provide a useful output signal with bending in both directions, comprising  
applying resistive ink to a substrate,  
bending the substrate into a concave shape;  
drying the ink,  
straightening the substrate to produce micro-cracks that are partially open when the sensor is not curved.

49. A flex sensor comprising  
a flexible film strip overprinted with  
conductive leads connected to  
an area of resistive material whose resistance varies as the strip is flexed,  
said flexible film strip laminated to  
a stiffer base layer having a shape set into an arc and attached to  
a compliant or spring-like support.

50. The flex sensor of claim 49, wherein the spring-like support is attached to two surfaces or objects that will undergo relative displacements and the set shape 0 comprises the film strip bent into an arched shape so that the resistive coating is flexed convexly by the relative displacements.

51. The flex sensor of claim 50, wherein the base layer has ends that are shaped to allow attachment to the surfaces or objects by a flattened tab.

52. The flex sensor of claim 49, wherein the film strip in the area of the resistive material contacts the support surface that maintains a neutral shape, unless a force or torque is applied across it.

53. The flex sensor of claim 49, wherein the base layer is shaped so that the arc shape is maintained in the absence of external loads or constraints.

54. The flex sensor of claim 53, wherein the base layer has varying thickness or width along its length.

55. The flex sensor of claim 53, wherein the base layer has configuration features to increase or decrease its compliance.

56. The flex sensor of claim 55 wherein the configuration features are slots, ribs, or corrugations.

57. The flex sensor of claim 49 wherein the flexible strip is mounted to the concave side of the arched base layer such that the resistive material is between the flexible strip and the base layer.

58. A flex sensor comprising  
a compliant arch support comprising  
a base material having a shape set into an arc to which is applied  
conductive leads connected to  
an area of resistive material whose resistance varies as the strip is flexed.

59. A method for determining the relative displacement or force and torque  
loads of two surfaces or objects comprising  
forming a flex sensor comprising a flexible film strip overprinted with conductive  
leads connected to an area of resistive material whose resistance varies as the strip is  
flexed, said flexible film strip laminated to a stiffer base layer,  
bending the film strip into an arched shape  
attaching the flex sensor to the two surfaces or objects so that the resistive  
coating is flexed convexly by the relative displacements, and  
displacing the two surfaces or objects and determining from the variation in  
resistance either the relative displacement or force or torque loads.

60. The method for determining the relative displacement or force and torque  
loads of two surfaces or objects of claim 59, further comprising the step of setting the  
belt tension to a range that is optimal for the sensor by use of an adjustable attachment.

61. The method for determining the relative displacement or force and torque

loads of two surfaces or objects of claim 59, wherein the displacement of the connected objects is constrained to either linear or rotational displacement.

62. The method for determining the relative displacement or force and torque loads of two surfaces or objects of claim 61, wherein the relative rotation between the two objects is about an axis of rotation positioned in relation to the sensor element so as to not result in an additional linear displacement.

63. A flex sensor comprising

a strip of flexible film coated on a central section by a small area of material having an electrical resistance that varies with flexure of said film,  
said central section of said strip formed into an arched shape having a convex surface, with said resistive material on the convex surface and such that the ends of said strip are shaped to allow attachment to mechanical elements.

64. The flex sensor of claim 63 where linear and rotational displacements of the ends of said strip will increase or decrease the curvature of said strip and cause a corresponding increase or decrease in the resistance of said resistive material.

65. The flex sensor of claim 63 having the ends of the ends of said strip affixed to mechanical elements wherein linear or rotational displacement between said elements is sensed or measured.

66. The flex sensor of claim 65 wherein the said mechanical elements are constrained so as to allow only linear displacement along an axis parallel to an axis of said strip so as to sense or measure only linear displacement on a single axis.

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67. The flex sensor of claim 65 wherein the said mechanical elements are constrained to allow only rotational displacement around an axis parallel to the surface of and perpendicular to an axis of said strip so as to sense or measure only rotation displacement on a single axis.

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68. The flex sensor of claim 63 wherein said strip is adhered to a backing of a material which is elastically compliant with a stiffness significantly greater than said strip and where a central section of said strip and said backing are together formed into a arched shape and such that the adhered ends of said strip and said backing are shaped to allow attachment to other mechanical elements.

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69. The flex sensor of claim 63 wherein the change in curvature of said strip due to an applied force or torque is limited by the attachment of an elastically compliant spring element affixed to said strip or to other mechanical elements to which the ends of said strip are affixed.

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70. A device for sensing and measuring linear force and rotational torque comprising a strip of flexible film coated on a central section by a small area of material

having an electrical resistance that varies with flexure of said film,

    said central section of said strip formed into an arched shape having a convex surface, with said resistive material on the convex surface and such that the ends of said strip are shaped to allow attachment to mechanical elements

5      further having said strip adhered to a backing of a material which is elastically compliant with a stiffness significantly greater than said strip and

    where a central section of said strip and said backing are together formed into a arched shape and such that the adhered ends of said strip and said backing are shaped to allow attachment to other mechanical elements, and

0      where forces and torques applied between the ends of said strip and backing increase or decrease the curvature of said strip and backing limited by the stiffness of said backing and cause a corresponding increase or decrease in the resistance of said resistive material.

5      71. The flex sensor of claim 68 arranged such that the ends of the ends of said strip are affixed to mechanical elements to sense or measure linear force or rotational torque between said elements.

72. The flex sensor of claim 68 where the said mechanical elements are constrained 0 so as to allow only linear displacement along an axis parallel to the main axis of said strip so as to sense or measure only linear force on a single axis.

73. The flex sensor of claim 68 where the said mechanical elements are constrained so as to allow only rotational displacement around an axis parallel to the surface of and perpendicular to the main axis of said strip so as to sense or measure only rotation torque on a single axis.

74. The flex sensor of claim 69 where the ends of said device are affixed to the opposite ends of a gap or convoluted section of a flexible band, which may be a strap, belt, or cord, such that a tensile load applied to said band is transmitted along the length of said device, with said tension force affecting the curvature of said sensing device.

75. The flex sensor of claim 74, for sensing and measuring respiration of a subject, where said band forms a loop that encircles the chest or abdomen of the subject such that expansion and contraction of the chest or abdomen due to respiration by the subject causes a corresponding increase and decrease the tension of said band.

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76. The flex sensor of claim 75 where a multiplicity of said sensing devices are affixed to a multiplicity of said bands.

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77. The flex sensor of claim 74 where a protective cover is positioned to partially surround said sensing device and affixed to said band in a compliant manner so as not to interfere with the application of tension to said sensor.

78. The flex sensor of claim 74 where said band is employed to bind, fix, compress,

or pull a multiplicity of other elements and where said sensing device is applied as a means to sense or measure tension in said band.

79. The flex sensor of claim 68 where one end of said device is affixed to the end of a flexible band, which may be a strap, belt, or cord, and the other end of said device is affixed to a rigid or semi-rigid element such that a tensile load applied to said band relative to said element is transmitted along the length of said device, with said tension force affecting the curvature of said sensing device.

0 80. The flex sensor of claim 79, applied as a means for sensing and measuring respiration of a subject where said band, said rigid element, and optionally other elements for a loop that encircles the chest or abdomen of said subject such that expansion and contraction of the chest or abdomen due to respiration cause a corresponding increase and decrease the tension of said band.

5 81. The flex sensor of claim 80 where a multiplicity of said sensing devices are affixed to a multiplicity of said bands.

82. The flex sensor of claim 79 where a protective cover is positioned to partially surround said sensing device and is affixed to or corresponding in shape with said rigid element.

83. The device and arrangement of claim 79 where said band and said rigid element are employed to bind, fix, compress, or pull a multiplicity of other elements and where said sensing device is applied as a means to sense or measure tension in said band.

5 84. A method for processing a combined signal that consists of the combination of a varying and unsteady primary input signal that is a measure of respiration of a subject, and a multiplicity of additional input signals that may be steady, varying, or random and that are the result of movement and muscular efforts of said subject and which detects the presence and certain parameters of the primary input signal by separation of said 0 combined signal into a multiplicity of frequency bands and, within a frequency band, compares successive wave cycles to determine the likelihood that they indicate the presence of said primary input signal.

5 85. The method of claim 84 where pairs of successive wave cycles of said signal are compared by amplitude and period and a metric is generated based on a weighted sum or average of the relative change in period, the relative change in amplitude, and the greater of the relative change in period and the relative change in amplitude.

86. A carrier for sensors arranged to be worn by a subject for providing  
0 electrical signals representative of physical parameters of the subject, said carrier comprising  
two flexible extensions containing external sensors,

a central housing comprising electronics residing on a PC board to receive and interpret the electrical signals from the sensors, and to process the signals at the location of the subject,

EKG sensors comprising pads of conductive rubber wired to the electronics  
; said electronics having a comparator that looks for the high slew rate of the R-  
wave component of an EKG pulse.

87. The carrier for sensors arranged to be worn by a subject of claim 86,  
wherein the EKG sensors are attached to a back surface of the extensions and the  
0 carrier further comprises a harness.

88. The carrier for sensors arranged to be worn by a subject of claim 87,  
wherein the harness is stretchable so that the EKG sensors remain in contact with the  
same portion of skin as the subject breathes.

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89. A method for analysis of signals affected by flex sensors worn by a subject  
to determine respiration rate or motion comprising  
0 using an electric circuit to determine high and low peaks in the signals,  
determining the peak to peak (p-p) time and amplitude,  
comparing the p-p time and amplitude to predefined min and max cycle times  
and a threshold amplitude to determine the presence or absence of breathing,  
reporting the cycle period, p-p amplitude, and ratio of inhalation to exhalation.

90. The method for analysis of signals affected by flex sensors worn by a subject to determine respiration rate or motion of claim 89, further comprising filtering to remove signals above ~1Hz.

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91. The method for analysis of signals affected by flex sensors worn by a subject to determine respiration rate or motion of claim 90, further comprising filtering to remove movement signals.

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92. The method for analysis of signals affected by flex sensors worn by a subject to determine respiration rate or motion of claim 90, further comprising scoring the output signal over a period of time.

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93. The method for analysis of signals affected by flex sensors worn by a subject to determine respiration rate or motion of claim 92, wherein the period of time is in the range of approximately 60-180 seconds.

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94. The method for analysis of signals affected by flex sensors worn by a subject to determine respiration rate or motion of claim 89, wherein an electronic circuit reports as the presence of body motion signals above 1 Hz comprising applying a high pass filter to the signal, rectifying the result,

comparing the result of rectifying to a reference,

if the result is greater than the reference, switching on an output flag and

initializing a timer,

having an output remain on until the timer runs out, such that activities such as

5 walking will cause the output to remain on continuously.

95. The method for analysis of signals affected by flex sensors worn by a subject to determine respiration rate or motion of claim 89, wherein an electronic circuit reports the presence of body motion as seen as signals above 1 Hz comprising

0 applying a high pass filter to the signal,

rectifying the result,

processing the rectified signal with a low-pass filter with a >1 sec cutoff to

generate an envelope signal,

comparing the envelope signal to a pre-defined reference level, and

.5 generating a yes/no output or reporting multiple levels, signal frequency, or peak values.

96. A carrier for sensors arranged to be worn by a subject comprising

an electronic circuit including a processor,

20 a respiration motion sensor sensitive to localized upper-body motions and

an accelerometer for sensing any motion of the subject's torso, wherein the

electronic circuit puts out a pulse-width-modulated pulse train that is timed by the

processor, and

wherein the respiration motion sensor is a flex sensor and  
the electronic circuit determines a confidence level for the accelerometer based  
upon consistency of the reading of the flex sensor and the accelerometer.